Capturing nonlinear interaction between fluids and fiber-reinforced composite materials: a unified mathematical framework

Suncica Canic
Cullen Distinguished Professor
Department of Mathematics
University of Houston

Mesh-reinforced structures and fiber-reinforced structures arise in many engineering and biological applications. Examples include air domes and space inflatable habitats, vascular stents supporting a compliant vascular wall, and aortic valve leaflets. In all these examples a mesh or a collection of fibers is used to support an elastic structure, and the resulting composite structure has novel mechanical characteristics preferred over the characteristics of each individual component. These structures interact with the surrounding deformable medium, e.g., blood flow or air flow, or another elastic structure. Modeling and computer simulation of this class of problems is important for manufacturing and design of novel materials, for a design of space habitats, and for a design of novel medical constructs.

In this talk we present a *unified approach* to the study of mesh or fiber-reinforced shells and their interaction with incompressible, viscous fluids and 3D elastic structures. The approach is based on dimension reduction and operator splitting strategy. Mesh-like structures are modeled as mathematical 1D hyperbolic nets using dimension reduction. The resulting model is coupled to the elastodynamics of a membrane or a shell, and this mesh-reinforced shell model is then coupled to the flow of a viscous incompressible fluid and/or the elastodynamics of a 3D structure. Two-way coupling is enforced between all the different physical models in this multi-physics problem. An operator-splitting strategy is employed to solve the problems numerically, and in the main steps of the existence proof.

This talk we will provide an overview of the modeling, numerical method development and analysis of this class of problems. Numerical simulations will be presented to illustrate the results.

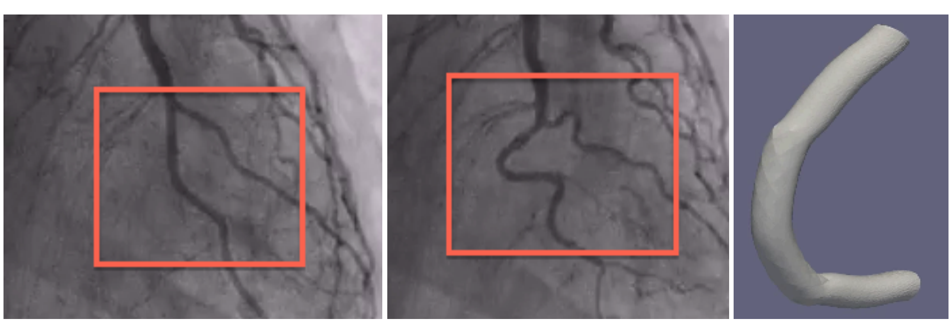

Figure 1. The left and middle panels show a patient angiogram at diastole (left) and systole (middle) showing coronary arteries on the surface of a beating heart. Right: Our simulation of coronary artery at systole containing a vascular metallic mesh called a stent. Fluid-structure interaction between blood flow, multi-layered vascular wall, vascular stent (mesh), and contraction of the heart muscle is simulated using the approach described above.